3.7 Study 2 Experimental Methodology and Approach

Braking in Response to Expected FCW Crash Alerts Under Lead Vehicle Stationary Conditions / Unexpected Braking Event

Building upon the solid foundation provided by the results obtained from CAMP Study 1, this study examined how and when to present crash alert information to both an attentive and relatively inattentive driver. An overview of the experimental methodology and approach used in this study is shown in Table 3-11, and an overview of the order of experiment events (or procedures) in this study is shown in Table 3-12. A subset of the test participants used in CAMP Study 1 was tested. Drivers in this study were fully informed that the purpose of the study was to address the usefulness of FCW system crash alerts for helping drivers avoid rear-end collisions.

In this study, drivers were asked to brake in response to a FCW system crash alert as an attentive driver while approaching the stationary (or parked) surrogate target at a steady speed of either 30 or 60 mph. These types of trials are subsequently referred to as *Alerted Stationary Trials*. These two lead vehicle stationary conditions were previously examined in CAMP Study 1. Hence, driver's braking behavior with a crash alert could be compared to previous data obtained under identical conditions without a crash alert (for the same driver), which is discussed toward the end of this Chapter immediately prior to the General Discussion section. Three different crash alert timing approaches were examined. Immediately after a trial, drivers were asked to judge the appropriateness of the FCW system crash alert timing with the following 7-point scale:

What is your opinion about when the crash alert was presented?

1	2	3	4	5	6	7
Much Too Early	*Moderately Early*	*Slightly Early*	*Just Right*	*Slightly Late*	*Moderately Late*	*Much Too Late*

When the test was allegedly over, the Surprise Moving Trial was introduced. The *surprise trial technique* involved the backseat-experimenter engaging the driver in "semi-structured", context-appropriate, natural, non-suspicious dialog. This type of trial is subsequently referred to throughout this paper as the *Surprise Moving Trial*. This Surprise Moving Trial was then followed by two comparable alerted trials with the same alert type. These types of trials will be subsequently referred to throughout this paper as *Follow-On Moving Trials*.

Four different, 1-stage, dual-modality crash alert types were investigated, which were each examined with three different crash alert timing approaches. The timing of the crash alert information was based on modeling results from CAMP Study 1, explained in further detail below. For the Alerted Stationary Trials and Follow-On Moving Trials, driver brake RT was assumed to be 0.52 seconds, based on piloting work conducted with four drivers. This driver brake RT was intended to allow an alerted driver to experience hard braking onset at the range predicted based on the modeling of Study 1 findings (discussed below). For the Surprise Moving Trial, driver brake RT was assumed to be 1.50 seconds. Similarly, this driver brake RT was intended to allow an inattentive or distracted driver to experience hard braking onset at the range predicted based on the modeling of Study 1 findings (discussed below). Olson (1996) states that for "reasonably" straightforward situations, 85%-95% of drivers will respond with a perception-response time of 1.5 seconds or less after the first appearance of the object or condition of concern. This tentatively suggested that a 1.5 second assume driver brake RT value would be a good choice for allowing ample time for the vast majority of drivers to brake to avoid a rear-end collision, but the trade-off between this perception-RT value and avoiding excessive in-path nuisance (or 'too early") alerts remains unclear.

3.7.1 Subjects

Test participants consisted of four males and four females in each of three different age groups; 21-31, 41-51, and 61-67 years old. Corresponding mean ages for these three groups were 26, 46, and 64 years old, respectively. Each driver was tested individually in one approximately 2 to 2 ½ hour sessions and paid $150 for their participation. Drivers were recruited by an outside market research recruiting firm, and were required to be CAMP Study 1 participants. Drivers who were ultimately allowed to participate were mailed the information letter shown in Appendix A1 prior to testing. A copy of the informed consent statement is provided in Appendix A2, which describes the various conditions that ruled out potential drivers from participating (which were nearly identical to the conditions used in CAMP Study 1).

3.7.2 Test Site

Data was gathered on the same straightaway used in CAMP Study 1. The road was closed to all other traffic during testing. All testing was conducted under daytime conditions under dry road and dry weather conditions.

3.7.3 Test Vehicles and the "Surrogate" (Lead Vehicle) Target

The driver's (or subject's) vehicle, the mock-up surrogate lead-vehicle and the lead (tow) vehicle were identical to those used in CAMP Study 1. These three primary elements of the experimental apparatus will be subsequently referred to as the *subject vehicle (SV), surrogate target,* and *principal other vehicle (POV),* respectively.

The SV front seat, passenger-side experimenter and POV driver were trained General Motors Milford Proving Ground test drivers who had previous experience conducting brake tests. The SV and the POV test drivers communicated during the study via digital radio communication.

3.7.4 Data Acquisition System

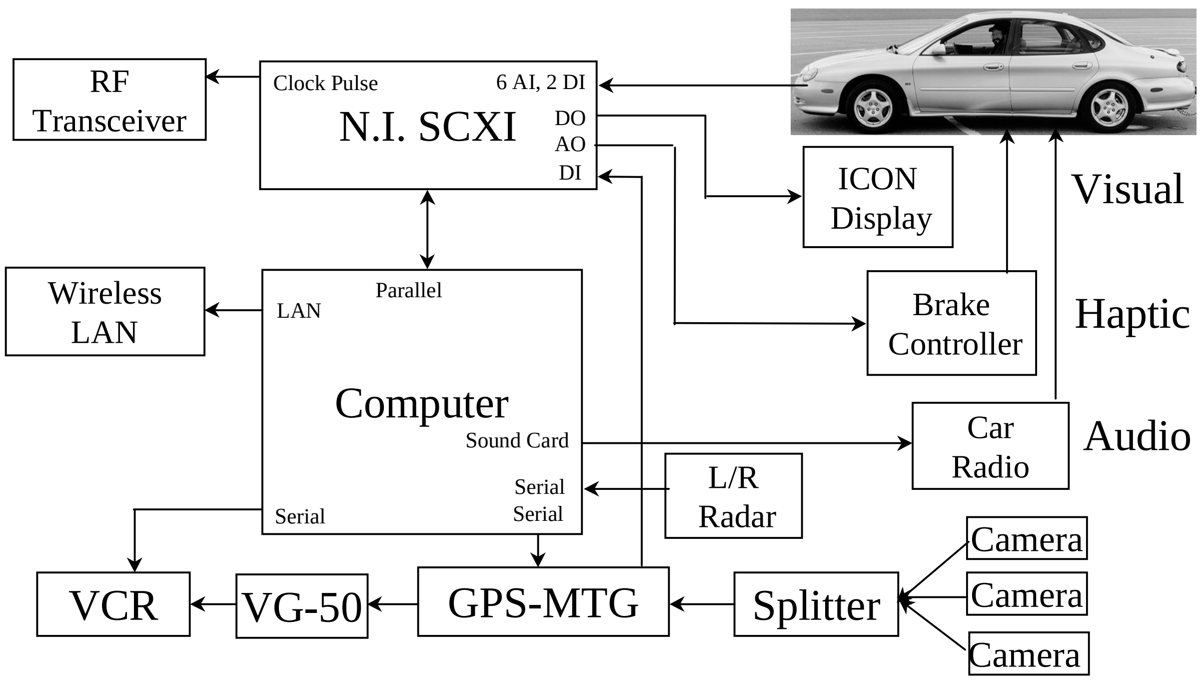
The data acquisition system used was identical to that used in CAMP Study 1, with the exception of the changes noted below.

Instrumentation

The two computers, one in each car, were linked together using a wireless local area network (or LAN). This link was used to control the beginning and end of a test trial. In addition, information about POV speed and POV acceleration levels were transferred to the SV. VI Engineering using National Instrument Labview Software developed the data acquisition program. The signal-conditioning interface (N.I. SCXI) was changed relative to Study 1 to provide more inputs and outputs to accommodate the various crash alert modality components. Figure 3-26 provides concept or block diagrams of the SV and POV instrumentation. Figure 3-27 shows the position of some of the main pieces of equipment installed in the vehicles. The equipment in the trunk was mounted in a rack to prevent sliding. The computer was mounted on a pedestal in the back seat along with the video monitor. The antennas were fastened to the rooftop above the rear seat. Table 3-13 provides a detailed list of POV and SV instrumentation used during the testing. Items in this table listed with no cost were provided by the CAMP partner companies (GM or Ford).

Figure 3-26 Concept Diagrams of the Subject Vehicle and Principal Other Vehicle Instrumentation

Subject Vehicle Instruments



Principal Other Vehicle Instruments

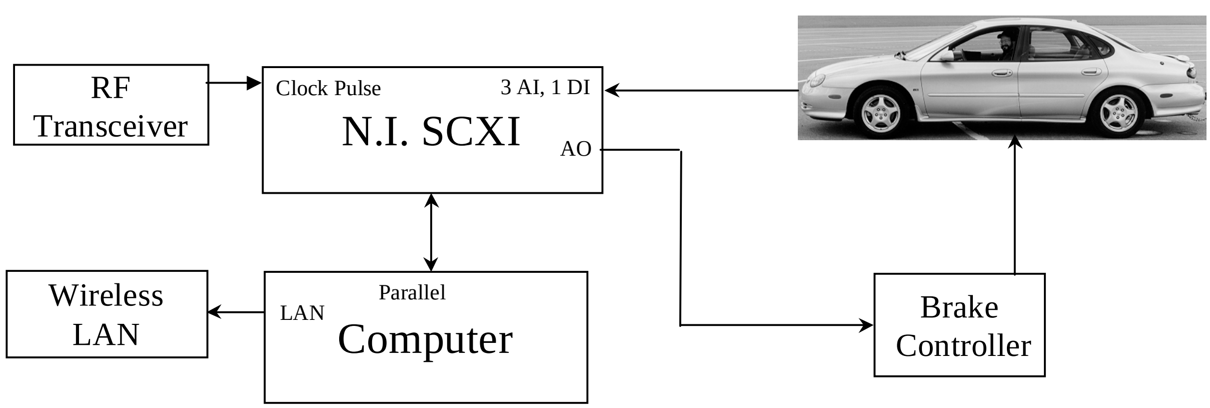


Figure 3-27 Illustration of Equipment Installations

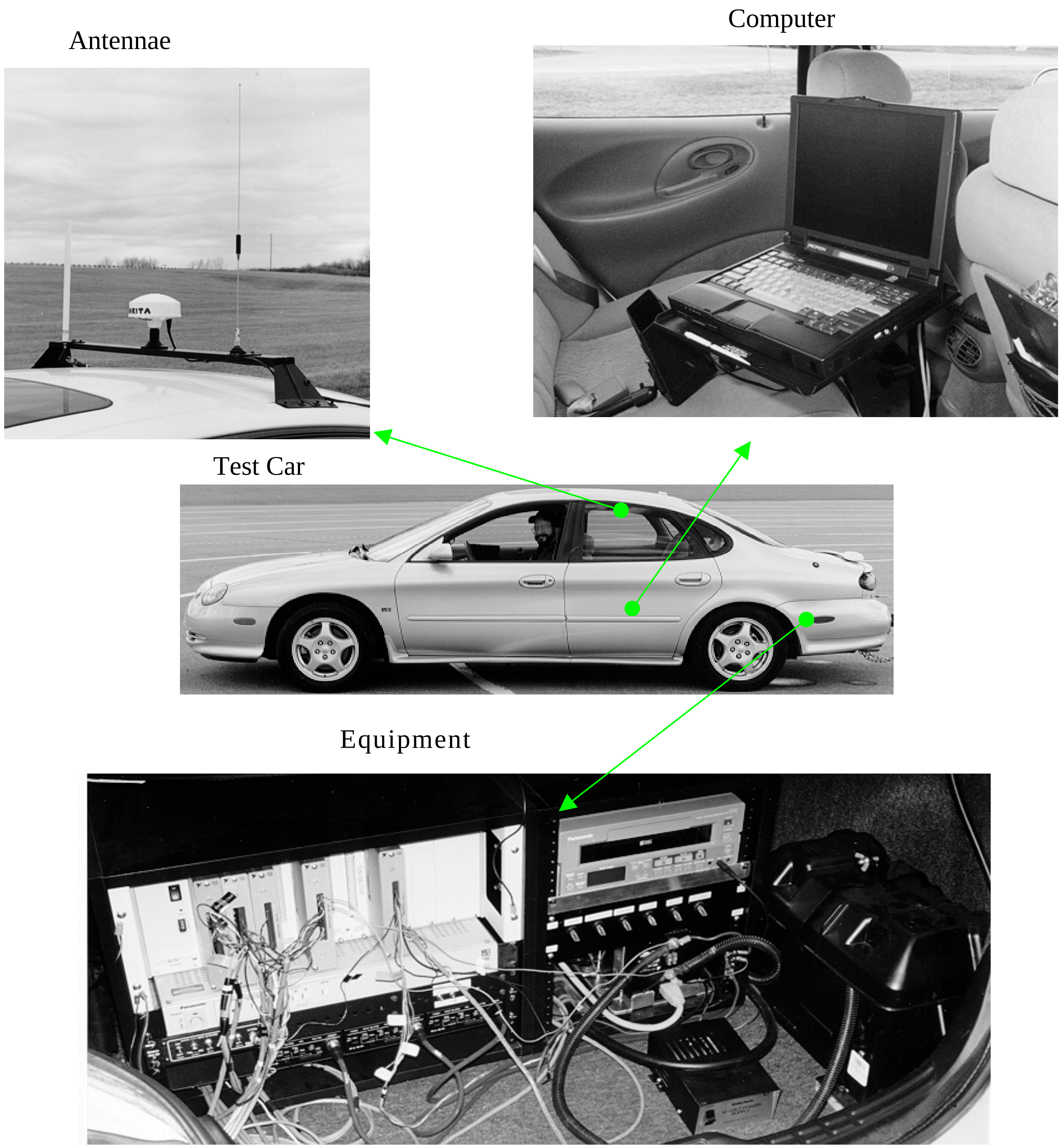


Table 3-13 Equipment List for the Subject Vehicle (SV) and the Principal Other Vehicle (POV)

SV Instruments	Manufacture	Model	Serial Number	Cost
Test Car	Ford Motor Company	1997 White Taurus SHO	1FALP54N9VA 140762	$15,000
Power Inverter	Trip Lite	PV-400		$170
Signal chassis	National Instruments	SCXI chassis		$11,000
Distance Sensor	Mitsubishi Laser Radar Control Unit, Head	EMZ503-01 X4T25571T1	001	$3,300
Passenger Brake	Safety Industries	Titan Dual Control Brake		$620
Video Monitor	Citizen	M398	C6-02692	$280
VCR	Panasonic	AG-5700-P	16TB00090	$1,450
4 to 1 Video	Panasonic Quad System	WJ-420	6ZB22758	$1,250
Camera	Elmo	MN401E Camera	131879, 131862, 131842	$7,800
Time Code Generator	Horita	RM-50II GPS	MT-4393033	$1,800
Time Code Converter	Horita	VG-50	VB-757850	$265
GPS Receiver	Hortia	28529-61	0260034705	$1,215
Computer	Micron	NBK001221-00	758041-0001	$4,800
Computer desk	Mobile Planet	MP320101 Mobile desk		$180
Accelerometer	Lucas Schaevitz,	LSBP-1	38922	$0
Load Cells	Entran Sensors	ELF-1000I-100	96L96L17-Y16,Y21,Y17	$2000
Position Transducer	SpaceAge Control	160-1215	4580	$574
Heads-Up-Display	Delco Electronics	Eye-Cue 2000	002	$1500
High-Head-Down Display	General Motors	HHDD		$0
Brake Pulse	Delphi	Brake Pulse System		$39,984

POV Instruments	Manufacture	Model	Serial Number	Cost
Test Car	Ford Motor Company	1997 Silver Taurus SHO	1FALP54N7VA 140761	$15,000
Power Inverter	Trip Lite Power	PV400		$170
Signal Chassis	National Instruments	SCXI chassis		$11,000
Brake Booster	ITT Industries	Analog Booster System	3-33826-69	$37,561
Trailer Brake	Kelsey Energize	Electric Brake Control Unit		$0
Computer	Micron	NBK001221-00	758041-0002	$4,800
Computer desk	Mobile Planet	MP320101 Mobile desk		$180
Accelerometer	Lucas Schaevitz	LSBP-1	38923	$0
Accelerometer	Valentine Research	G-analyst	3035000200	$0
	Valentine Research	G-analyst display	0774000100	$0
Radio	NexTel	I370XL	089AXYK475	$201
	FJW Industries	Find-R-Scope	9082	$0
Accelerometer	Valentine Research	G-analyst	8925000200	$0
	Valentine Research	G-analyst display	5774000100	$0

3.7.5 Visual, Auditory and Brake Pulse Crash Alert Modality Components

The driver was simultaneously presented crash alerts from two sensory modalities, sometimes referred to as a *1-stage, dual-modality crash alert*. The modality components of the various crash alerts examined are described below.

Visual Crash Alert Modality Components

The high head-down display was placed on top of the instrument panel, close to the cowl of the windshield, and centerline to the driver. This display was supplied by GM, and is shown in the top half of Figure 3-28. This figure illustrates the visual display format resulting from the visual icon selection process, which is explained, in detail in Appendix A18. The crash alert icon (a "half car-star-half car" symbol) and the word "WARNING" (printed below) appeared as amber on a black background. With respect to the eyellipse centroid, the following discussion provides specific information on the position and size of this high head-down display visual crash alert. The center of the icon was positioned at a 7.7^0 look-down angle below the driver's visual horizon, and at a 0.947 meter distance. For a reference point, the look-down angle to the front hood (i.e., where the hood visually occludes the roadway) was also 7.7^0, and the look-down angle to the center of the instrument panel cluster was 19.3^0. The area encompassed by both the visual icon (a "half car-star-half car" symbol) and the word "WARNING" subtended a 0.8^0 high by 1.2^0 wide visual angle area. The area encompassed by the visual icon subtended a 0.3^0 high by 0.9^0 wide visual angle area. The area encompassed by the capitalized word "WARNING" subtended a 0.2^0 high by 1.2^0 wide visual angle area. These capitalized letters were 3 millimeters in height, and printed in Helvetica bold font type.

The high head down display module consisted of four lamps enclosed in a machined aluminum housing with baffles positioned between the lamps. The exterior was painted black, and the inside was a white color. The lamps were mounted on a printed circuit board that slides into the housing from the front. The panel with the crash alert icon was plastic and snapped into the front of the housing. Four icons were selected and sized to be placed on a Polycarbon material, which was done by Lettergraphics of Detroit. These icons were selected based on results from the comprehension estimation procedure during the first phase of the visual icon selection procedure. The operation of the lamps was controlled through a signal-conditioning interface. A breadboard of relays was built to switch the lamps. The relays were driven by digital TTL signals, which provided the ability to flash the icon.

The head-up display (or HUD) was projected off a combiner as a virtual blue/green image and appeared below the driver's line of sight and centerline to the driver. The format of the HUD crash alert was identical to that used with the high head-down visual display, which is shown in the bottom half of Figure 3-28. (The reader should note that the HUD photograph in this illustration was taken off center.) With respect to the eyellipse centroid, the following discussion provides specific information on the position and size of this HUD crash alert. The HUD appeared at approximately a 1.214-meter image distance. The area encompassed by both the visual icon and the word "WARNING" subtended a 1.4^0 high by 3.4^0 wide visual angle area. The

Figure 3-28 Illustrations of the High Head-Down Display (HHDD) and the Head-Up Display (HUD) Visual Crash Alerts

area encompassed by the visual icon subtended a 0.7^0 high by 2.5^0 wide visual angle area. The area encompassed by the capitalized word “WARNING” subtended a 0.5^0 high by 3.4^0 wide visual angle area. The HUD look down angle relative to the driver’s visual horizon was adjustable by the driver, and was not measured individually for each subject (which is a time-consuming procedure). Since this aftermarket HUD was not designed for the test vehicle, there is no straightforward way to characterize the HUD look down angle. However, given that subjects were instructed to and were able to adjust the HUD to be positioned above the front hood, a lower bound for the bottom of HUD crash alert display is the look-down angle to the front hood (i.e., where the hood visually occludes the roadway), which was 7.7^0 relative to the eyellipse centroid. Based on previous HUD experience, the “nominal” look down angle to this HUD crash alert was likely to be about 4^0-5^0.

This head-up display was an after-market Eye-Cue 2000 HUD product offered by Delco Electronics. The display is an 80 by 40 pixel display with plastic housing and combiner glass, and a separate DC to DC power supply. A controller to drive the display was developed by Danlaw Incorporated. The controller, a Motorola 68HC11, was programmed to display various crash alert icons, as well as a “CAMP” test image. Four digital TTL input lines were used to select which icon to display. The intensity (or brightness) of the display was controlled by a knob on the right side of the housing, which can be seen in Figure 3-28. The vertical location of the HUD image in the driver’s field of view was controlled by tilting the combiner glass in a fore/aft motion. As can be seen in Figure 3-28, this aftermarket HUD unit was mounted on top of the instrument panel in front of the driver. Figure 3-29 illustrates the interconnections of the HUD components, HUD, power supply, and the controller.

Hence, overall, the HUD visual crash alert subtended a larger visual angle than the HHDD visual crash alert in both the height and width dimensions. In addition, the HUD appeared at approximately half the look down angle relative to the HHDD (or put in another way, the HUD appeared twice as close to the driver’s visual horizon).

Auditory Crash Alert Modality Components

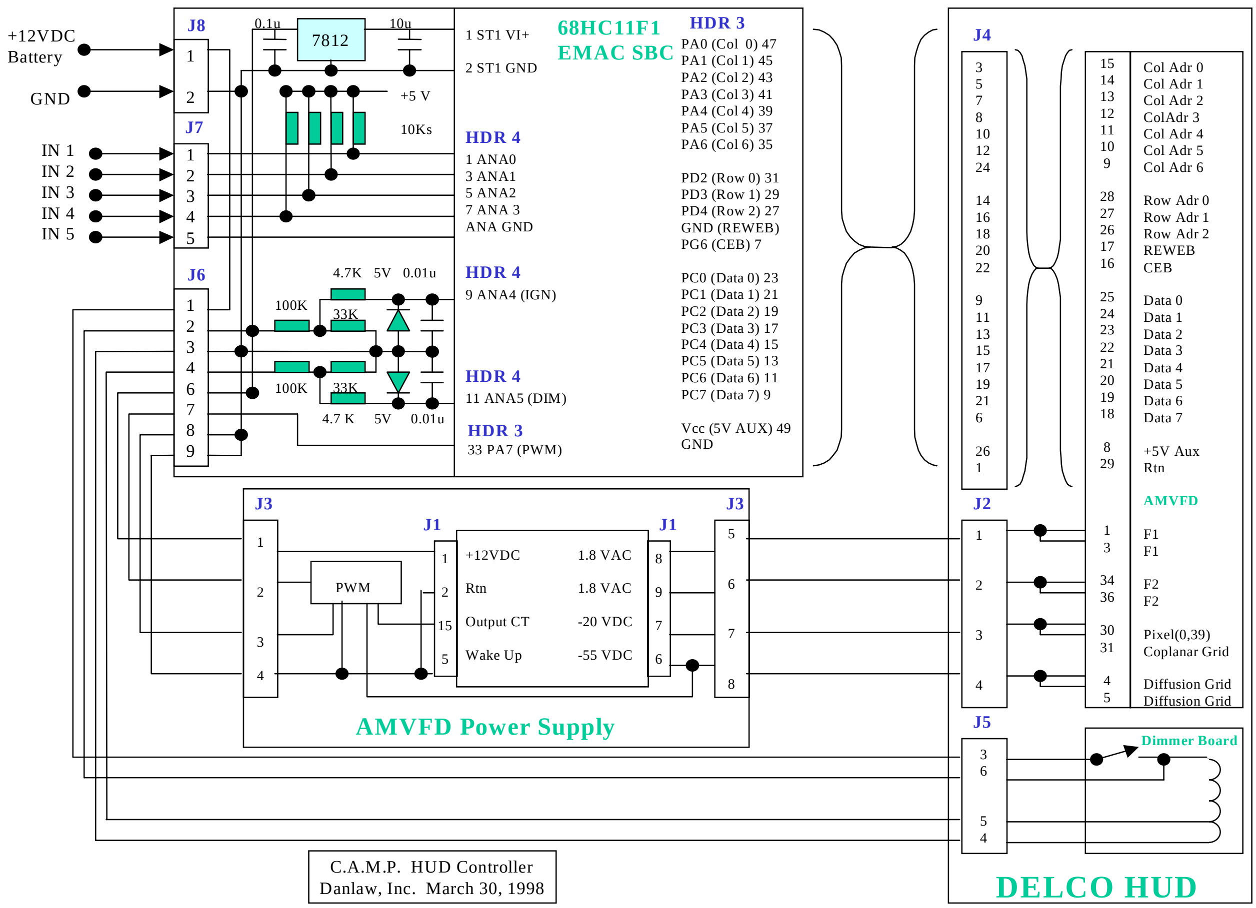
The non-speech and speech crash alerts were digitized “WAV” sound files on the computer that were played through the front car speakers at a 67.4 dBa sound level (averaging over left and right channels). The computer sound output was fed through the car’s radio system by using a cassette adapter in the radio. The radio was turned on and set to cassette mode. The crash alert sound intensity (or loudness) was set using the radio volume controls. The non-speech and speech sounds selected were based on results from the auditory alert selection process, which is explained in detail in Appendix A19.

Haptic Crash Alert Modality Component

The brake pulse alert involved a brief (about 600 ms) vehicle jerk, involving a peak deceleration of 0.24 g's. (For the interested reader, a detailed description of the time-course of the brake pulse alert is shown in Appendix A16). This brake pulse profile was established during informal pilot testing with four drivers, since there were no relevant driver performance data available. In general, the goal of this pilot work was to allow the brake pulse to be clearly noticeable while avoiding, as much as possible, shifting the driver out of their driving position. Delphi Chassis Systems was contracted to supply the device that provided this example of a haptic crash alert. Delphi was required to modify the standard brake system on the SV so that the brakes could be pulsed from a computer to generate a deceleration rate between 0.15 to 0.30 g's for a duration between 0.1 to 2.0 seconds. All other brake functions were to operate as a standard brake system, and this device was required to not interfere with the normal operation of the vehicle brakes. The computer, using an analog output board, was to generate a 0 to 5-volt signal for the required brake pulse intensity and duration.

In response to these requirements, Delphi supplied and installed a brake modulation subsystem capable of applying up to a -0.30 g vehicle deceleration for speeds up to 60 mph on dry roads. A functional diagram of this subsystem is shown in Figure 3-30. This subsystem was controlled by a vehicle level controller by means of applying brake pressure to the front axle of the vehicle. The conventional base brake system and the ABS available on the car were not affected during manual braking by the driver. Any manual brake pedal application interrupted the add-on brake modulation and overrode any signal input to the modulation subsystem by the vehicle controller. The ABS and traction-control systems were not available (or operating) when the brake pulse was activated, which would be desirable from a production implementation perspective in order to address the activation of this alert on slippery surfaces. The CAMP computer interfaced to the embedded controller by 'System Command' and 'System Enable' signals. If the modulation subsystem detected a fault in its operation, a 'Fail Indicator' signal was sent to the CAMP Computer. To aid in problem-solving a fault, Delphi provided a software program. A separate serial interface was provided from the embedded controller for communication to the program. This program provided status information on the various internal parameters that could be used for trouble-shooting purposes.

Figure 3-29 Interconnections of HUD Components, HUD, HUD Power Supply, and the Controller



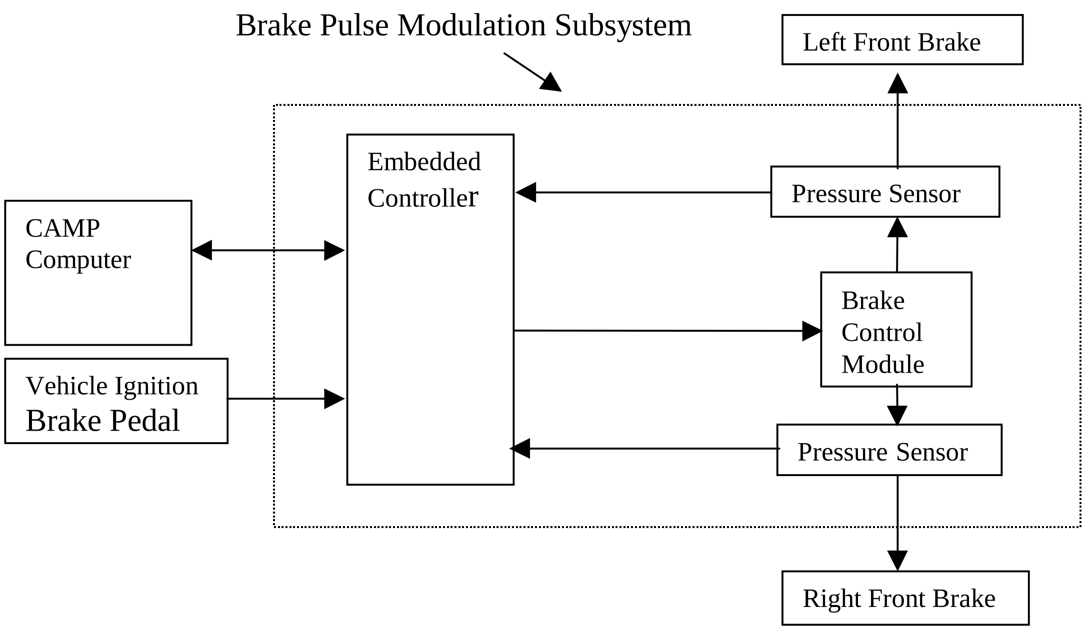


Figure 3-30 Brake Pulse Crash Alert Modulation Subsystem

3.7.6 Procedure and Design

Procedures Before and After Test Trials

After completing various pre-experiment forms and procedures (including the informed consent statement), subjects were escorted to the track. Drivers were then administered test instructions verbally (shown in Appendix A3), and asked to adjust the seat, steering wheel, and mirrors to their preferred position, and to fasten their shoulder harness and lap belt. It should be noted that subjects were instructed about the nature of the surrogate target, and more specifically, that this target was designed to allow low speed impacts. Subjects were also informed of the add-on passenger-side brake. Next, a sequence of test trials was conducted, which are described below. After the test trials were completed, subjects were escorted from the track, debriefed on the purpose of the study, and paid for their participation.

Test Phases / Driver Instructions

During the first phase of this study, drivers experienced trials in which the surrogate target was parked (or stationary). These types of test trials are referred to as *Alerted Stationary Trials*. Drivers were asked to approach the parked surrogate target at either 30 or 60 mph, and maintain a steady speed.

During the approach, a 1-stage, dual-modality crash alert was presented. Four separate crash alert types were evaluated, which are indicated below:

- Head-Up Display (HUD) + Non-Speech Tone
- High Head-Down Display (HHDD) + Non-Speech Tone
- High Head-Down Display (HHDD) + Speech
- High Head-Down Display (HHDD) + Brake Pulse

Drivers were instructed to brake immediately in response to the crash alert in order to avoid colliding with the artificial car. When the SV came to a complete stop, data collection was halted and the trial was ended.

Drivers were asked to make these braking responses under three different crash alert timing conditions, which are described shortly. During these alerted trials, drivers experienced 4 blocks of 6 trials each, with each block of trials dedicated to one crash alert type. The order of these crash alert type (or interface) blocks was appropriately counterbalanced across drivers. The six trials per block, were formed, by crossing the 2 approach speeds with the 3 crash alert timings. The approach speed changed every trial within a block, and the crash alert timing condition was randomized from trial-to-trial and appropriately counterbalanced across drivers.

After the Alerted Stationary Trials were completed, the second phase of the study began. In this phase, the driver was led to believe the test was over. An unexpected (surprise) braking event was then introduced in which the lead vehicle, traveling at 30 mph, suddenly braked at about a constant -0.38 g level of deceleration without brake lights. The crash alert type presented coincided with the type tested in the last block of test trials. This type of trial is referred to as the *Surprise Moving Trial.* In an attempt to create an inattentive driver prior to the unexpected braking event, the backseat experimenter engaged the driver in an active, naturalistic, 2-way conversation. This conversation typically occurred at the end of dialogue, which began with a brief informal debriefing discussion and ended with a “post-test” casual conversation. This conversation typically evolved around the driver’s summer vacations or job, as well as topics that evolved during the testing session. This surprise trial technique will be referred to as the “*Natural Conversation*” surprise technique.

The Surprise Moving Trial was then followed by two trials that were identical to the conditions of the Surprise Moving Trial, except that now drivers were fully aware that the lead vehicle would be braking. These types of trials will be referred to as *Follow-On Moving Trials*.

Crash Alert Timing Approach

For crash alert timing, an assumed total delay time (which included driver brake RT) and an assumed driver deceleration in response to the alert were input into straightforward, fundamental vehicle kinematic equations used for calculating the appropriate warning range to avoid a crash.

(These equations are described below.) These two critical, driver-behavior related inputs are now discussed in turn.

The assumed *total delay time* was the composite sum of three separate delay times, which are now described in the same time sequence in which they occurred. The *interface delay time* is defined as the time between when the crash alert criterion was violated and when the crash alert was presented to the driver. This delay is assumed to be 180 ms for all crash alert types examined except those including a brake pulse crash alert component. The brake pulse is assumed to onset after 410 ms, when the -0.10 g deceleration value was reached due to the brake pulse. (It should be noted that there was some variability associated with the time course of the brake pulse, which for the interested reader, is shown in Appendix A16). The *driver brake RT delay* is defined as the time between crash alert onset and when the driver triggered the brake switch. Based on discussions above, this delay was assumed to be 0.52 seconds for expected alerts, and 1.50 seconds for surprise alerts. The *brake system delay time* is defined as the time between braking onset and vehicle slowing, and is assumed to be 200 milliseconds. The assumed "*delay time range*" between crash alert criterion violation and vehicle braking is then the expected decrease in range during this total delay time, assuming the prevailing kinematic conditions (i.e., SV speed, POV deceleration) would continue during this total delay time. This delay time range, calculated as shown below, is added to a "*braking onset distance*" (described below) to calculate the desired warning range. In the equation below, "V" represents the current velocity (or speed), and dec_{SVM} and dec_{POVM} represents the current deceleration levels of the SV and POV, respectively. In this equation, the speed and deceleration variables should be expressed in feet/sec^2, and deceleration values are represented as negative values.

$$\text{Delay Time Range} = ((V_{SV} - V_{POV})(\text{Total Delay Time})) + (0.5\,(dec_{SV} - dec_{POV})((\text{Total Delay Time})^2))$$

The assumed driver deceleration response in response to the crash alert was based on the required deceleration equation developed/modeled from CAMP Study 1 findings, which is shown below and discussed in detail in Appendix A20. This equation is subsequently referred to as the *CAMP Required Deceleration Parameter* (or *CAMP RDP equation*). In this equation, deceleration values are represented as negative values. This equation expressed in feet/sec^2 is as follows:

$$\text{Required Deceleration } (dec_{REQ}) = -5.308 + 0.685(dec_{POV}) + 2.570(\text{if POV moving}) - 0.086(\text{delta V})$$

(An alternative version of this equation predicts required deceleration in g's is shown in at the end of Appendix A20). (To remind the reader, the required deceleration measure was defined as the constant deceleration level required for the driver to avoid the crash at braking onset, assuming the current speeds of the driver's vehicle and the lead vehicle, and assuming the lead vehicle continued to decelerate at the prevailing deceleration value). In the above equations, the "delta V" predictor variable represents the speed difference between the SV and POV *projected* at braking onset and "POV dec." represents the current POV deceleration level. (The "projection" described here, as well as the projections described below, were performed to be consistent with the Study 1 modeling efforts which focused on predicting the moment of braking onset.) In addition, the "if

POV moving" predictor variable is set to 0 if the POV is projected to be stopped at braking onset , and is set to 1 if the POV is projected to be moving at braking onset. Once again, in the above equation, the variables "delta V" and "dec_{POV}" should be expressed in feet/sec and feet/sec^2 respectively, which is consistent with the measurement units used in calculating delay time range above. These predicted required deceleration values are then converted to calculate a braking onset range or "braking onset range", using one of the three kinematic "case" equations described below. Given the assumed two driver behavior parameters described above, and assuming current speeds (for both the SV and POV) and the prevailing lead vehicle deceleration value, these kinematic equations produce an alert range such that the difference in speeds between the driver's vehicle and lead vehicle and the distance between the two vehicles reach zero values simultaneously (i.e., when the front bumper of the driver's vehicle barely contacts or touches the rear bumper of the lead vehicle).

The appropriate case equation used to calculate the braking onset range (Case 1, Case 2, or Case 3) is based on the projected movement state of the POV at braking onset (POV moving or POV stationary), and the projected movement state of the POV when the SV barely contacts the POV (contact when POV is moving or contact when POV is stationary) under the required deceleration prediction (or assumption). The braking onset range is then calculated by inputting the predicted required deceleration value into the appropriate case equation below. Once again, in the equations below, the variables need to be expressed in common measurement units, which should be consistent with those used in calculating the delay time range and predicted required deceleration values above. Furthermore, deceleration values are represented as negative values. In the equations below, V_{SVP} and V_{POVP} represent the projected speeds of the SV and POV speed at SV braking onset, respectively. That is,

$$V_{SVP} = V_{SV} + (dec_{SV}(\text{Total Delay Time}))$$
$$V_{POVP} = V_{POV} + (dec_{POV}(\text{Total Delay Time}))$$

<u>Case 1</u>: POV Stationary →

$$\text{Braking Onset Range} = \frac{(V_{SVP})^2}{-2*(dec_{REQ})}$$

<u>Case 2</u>: POV Moving, contact when POV is moving →

$$\text{Braking Onset Range} = \frac{(V_{SVP} - V_{POVP})^2}{-2*(dec_{REQ} - dec_{POV})}$$

<u>Case 3</u>: POV Moving, contact when POV is stationary →

$$\text{Braking Onset Range} = \frac{(V_{SVP})^2}{-2*(dec_{REQ})} - \frac{(V_{POVP})^2}{-2*(dec_{POV})}$$

This braking onset range is then added to the previously described delay time range to calculate a desired warning range. That is,

Warning Range = Delay Time Range + Braking Onset Range

This method of calculating a warning range will be referred to as the *CAMP Required Deceleration Parameter approach* (or the *RDP approach*). The reader should note that the RDP *approach* is different from the RDP *equation* described above. The RDP equation is but one of the input parameters used in the RDP approach to calculate a desired warning range. The required deceleration value (which is derived from the CAMP RDP equation) which is input into this Warning Range equation to calculate Braking Onset Range is distinctly different from commonly employed warning algorithms which assume a fixed driver deceleration response independent of driver speed and lead vehicle deceleration levels. Under the CAMP RDP equation, the assumed driver deceleration varies as a function of both the speed difference between the two vehicles (i.e., delta V) and lead vehicle deceleration levels. (For readers concerned with the details of implementing crash alert timing equations, it should be noted that the kinematic equations shown above were focused on closing scenarios encountered in these interface experiments. Additional logic and equations, which are not shown above, were also implemented in these experiments so that inappropriate alerts did not occur in normal, non-braking situations (e.g., when the range between the vehicles is increasing). In a production implementation, a crash alert algorithm will be exposed to a wide variety of driving situations, which will include the key closing scenario elements shown above, as well as the additional logic and equations required to handle normal, non-braking driving conditions and to issue alerts in unusual circumstances with crash alert timing that is equivalent to that described here.)

Drivers were tested with three different crash alert timing approaches. The first approach used the RDP crash alert timing approach described above. The remaining two approaches assumed the driver would brake in response to the crash alert harder than that predicted by the RDP crash alert timing, or put in another way, drivers would brake harder than what was observed/modeled in CAMP Study 1 without a crash alert. Hence, the RDP crash alert timing provided the most conservative timing assumption, or put in another way, the earliest, farthest crash alert timing assumption examined. The second crash alert timing approach assumed the driver decelerated in response to the crash alert with an additional 0.05 g’s relative to the RDP crash alert timing approach, and is subsequently referred to as the “RDP + 0.05 g” crash alert timing approach. The third, and most aggressive (latest, closest) crash alert timing approach, assumed the driver decelerated in response to the crash alert with an additional 0.10 g’s relative to the RDP crash alert timing approach, and is subsequently referred to as the “RDP + 0.10 g” crash alert timing approach. In each of these three crash alert timing approaches, if the predicted warning range was larger than the observed warning range, the crash alert criterion was violated and the crash alert was presented.

“Bail-out” visual markers were placed on the right-center portion of the driving lane to provide the front seat, passenger-side experimenter information on when to take over braking using the add-on brake. Separate markers were positioned for each of the three different approach speeds examined (30, 45, and 60 mph). The test drivers were to begin braking at the point the vehicle occluded the visual marker. The distances for these markers were formed by having a driver approach a test reflector target at 5 mph above the target approach speed, while the test driver used the add-on brake to brake to the bail-out visual marker. Repeated trials were performed with each of the test drivers, and the longest braking distance found at each of the three speeds were using to create the visual marker distances.

The visual alerts were presented as long as the crash alert timing criterion was violated, whereas both the auditory and brake pulse alerts played out for a maximum of one entire cycle. In the event that the “bail-out” auditory alert for the experiment was triggered, the “bail-out” alert interrupted the non-speech tone intended for the driver. The “bail-out” auditory alert for the front seat, passenger-side experimenter was also triggered based on the RDP crash alert timing approach, with assumed inputs of a 0.52 second driver (test driver) brake RT, and an assumed constant deceleration in response to the crash alert of -0.55 g’s. The “bail-out” sound, which was distinct from the non-speech tone employed, signaled to the experimenter to take over braking using the add-on brake. A black cardboard visual barrier was placed between the driver and the front seat experimenter which prevented the driver from anticipating (or being distracted by) the foot (braking) behavior of the experimenter, and allowed the experimenter to discretely let their foot hover over the add-on brake during a test trial.

Independent Variables Examined

For the Alerted Stationary Trials, the within-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse), crash-alert timing (RDP, RDP + 0.05 g, and RDP + 0.10 g), and (approach) speed (30 and 60 mph), and the between-subjects variables analyzed were age (younger, middle-aged, or older) and gender (male or female).

For the Surprise Moving Trial and the Follow-On Moving Trials, the between-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, or HHDD + Brake Pulse) and age (younger, middle-aged, or older).

Objective (or Performance) Measures Examined

Various performance measures were analyzed. The variable definitions, and the point in time during the braking maneuver in which the performance measures were analyzed (at POV braking onset, at SV braking onset, throughout the braking, end of the braking maneuver) are identical to that used in Study 1, with the exception of one new measure, driver’s brake reaction time (RT). This measure is defined as the time between crash alert onset and the driver contacting the brake (i.e., triggering the brake switch) in response to the alert.

Subjective Measures / Questionnaire Data

Immediately after each braking trial, drivers were asked to judge the appropriateness of the FCW system crash alert timing using the 7-point scale ranging from “much too early” to “much too late”, which is shown in the opening paragraphs of the “Study 2 Experimental Methodology and Approach” section. (In this study, drivers were also asked how well the urgency level suggested by the alert matched the timing of the alert on a scale ranging from “much too low” to “much too high”, with a “just right” mid-point. This question proved somewhat difficult to construct in a meaningful way for drivers, although these results were extremely consistent with the pattern of crash alert timing results reported below. Hence, the results from this “urgency level” question will not be discussed further.)

These timing appropriateness ratings were analyzed for each phase of the study using the same independent variables and analysis approach that was used to analyze the driver performance measures.

Several questionnaires were administered throughout the study. During the first phase of Alerted Stationary Trials, drivers rated each crash alert type after experiencing the block of 6 trials with a given crash alert type. This “*alert modality appropriateness*” questionnaire involved the driver rating each modality of the crash alert type just experienced on various attributes. Excerpts of this questionnaire are shown in Appendix A4. For the visual alerts, drivers rated the intensity, size, color, and location of the display. For the auditory (non-speech and speech) alerts, drivers rated the loudness and duration of the alert. In addition, drivers were asked whether the radio should be muted during the alert. For the brake pulse alert, drivers rated the strength of the vehicle jerk and the duration of the alert.

At the end of the study, drivers were asked to fill out three separate questionnaires. In the first questionnaire, drivers were asked to rate each of the 1-stage, dual-modality crash alert types experienced on 14 different statements. This “*crash alert appropriateness*” questionnaire is shown in Appendix A5. These statements involved the driver rating each of the four crash alert types on the 14 statements, in the order shown below. These statements were associated with “overall” ratings, crash alert noticeability, confusion, attention-getting properties, startle, interference with driving, annoyance, harmony, association with danger, and purchase interest. Each of these statements was rated on a 7-point scale ranging from Strongly Disagree to Strongly Agree.

Crash Alert Appropriateness Statement

1. This is a good method for presenting crash alerts to drivers.
2. This method would be clearly noticeable in the car.
3. This method would NOT be confused with other events happening either inside or outside the car.
4. This method would get my attention immediately if I was distracted and not concentrating on the driving task.
5. This method would NOT startle me, that is, cause me to blink, jump, or make a rapid reflex-like movement.
6. This method would NOT interfere with my ability to make a quick and accurate decision about the safest driving action to take (brake, steer, brake and steer, do nothing).
7. This method would NOT interfere with my ability to perform a quick and accurate emergency driving action.
8. This method would NOT annoy me if the alert came on once a week in a situation where no driving action was required.
9. This method would NOT annoy me if the alert came on once a day in a situation where no driving action was required.
10. This method would NOT appear out of place in a car or truck.
11. This method would clearly tell me that I am in danger and need to react immediately.
12. This method of presenting crash alert information has great potential for preventing me from getting in a rear-end accident.
13. This method of presenting crash alert information would get my attention without being overly annoying.
14. If cost were not an issue, I would be likely to purchase this type of crash alert feature when I purchased a vehicle.

In the second questionnaire completed at the end of the test, drivers were asked to create their own interface. This "*build an interface*" questionnaire is shown in Appendix A6. Drivers were first asked to build a 1-stage crash alert, and then asked to build a 2-stage crash alert.

In the third and final questionnaire, drivers were asked to name the FCW system. This "*name the system*" questionnaire is shown in Appendix A7. Drivers were first asked to name the system in an open-ended fashion, and then asked to rank order their top three name choices from the following set of proposed system names:

Proposed System Names

- Forward Collision Warning System
- Forward Crash Warning System
- Forward Accident Warning System
- Rear-end Collision Warning System
- Rear-end Crash Warning System
- Rear-end Accident Warning System
- Front-end Collision Warning System
- Front-end Crash Warning System
- Front-end Accident Warning System

3.7.7 Results and Discussion

Overview of Statistical Analysis Approach for Objective Measures

For the analysis of the objective (or performance) measures, a factorial Analysis of Variance (ANOVA) was performed for each relevant driver performance measure (dependent on whether the lead vehicle was moving or stationary) shown previously in Table 3-1. Data from the Alerted Stationary Trials, Surprise Moving Trial and Follow-On Moving Trials were analyzed separately during the statistical analysis. The criterion set for statistical significance was $p<0.01$ during the analysis of the Alerted Stationary Trials (Study 2), due to the large number of statistical tests carried out (which increases the probability of spuriously significant results (Hays, 1981). For the analysis of the Surprise Moving Trial (in Study 2 and Study 3) and the Follow-On Moving Trials data, the criterion set for statistical significance was $p<0.05$. Unless otherwise noted, all statistically significant results indicated met (and often exceeded) these adopted criterion.

Objective (Or Performance) Measures

Alerted Stationary Trials

The within-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse), crash alert timing (RDP, RDP + 0.05 g, and RDP + 0.10 g), and (approach) speed (30 and 60 mph), and the between-subjects variables analyzed were age (younger, middle-aged, or older) and gender (male or female). Results indicated main effects of age on the brake RT and TTC measures.

For the younger, middle-aged, and older groups, mean brake RTs were 491, 533, and 627 ms, respectively, and mean TTC values were 2.9, 2.7, and 2.8 seconds, respectively. There were also relatively robust main effects of crash alert type, crash alert timing, and speed. These effects found for various performance measures are shown in Table 3-14, Table 3-15 and Table 3-16 respectively. These effects will be discussed to help the reader get oriented to the large volume of data analyzed, however, it should be stressed that many of these main effects need to be interpreted in terms of higher-order interactions, which are discussed below.

Table 3-14 Significant Main Effects of Crash Alert Type on Various Measures During Alerted Stationary Trials (Study 2)

	At SV Braking Onset			
Crash Alert Type Condition	**Mean Brake RTs**	**Mean Current Dec. (g)**	**Mean Req. Dec. (g)**	**Mean TTC (sec)**
HUD + Non-Speech	502	-0.03	-0.42	2.8
HHDD + Non-Speech	509	-0.03	-0.42	2.8
HHDD + Speech	573	-0.03	-0.44	2.7
HHDD + Brake Pulse	617	-0.07	-0.39	2.9

Table 3-15 Significant Main Effects of Crash Alert Timing on Various Measures During Alerted Stationary Trials (Study 2)

	At Braking Onset				Throughout Braking			End of Braking
Crash Alert Timing Condition	**Mean Brake RTs (sec)**	**Mean Range (feet)**	**Mean TTC (sec)**	**Mean Req. Dec. (g)**	**Mean Actual Dec.**	**Mean Peak Dec. (g)**	**Mean Min. TTC (sec)**	**Mean Range (feet)**
RDP	575	213	3.1	-0.37	-0.52	-0.70	1.8	40
RDP + 0.05 g	547	193	2.8	-0.42	-0.56	-0.76	1.5	30
RDP + 0.10 g	529	173	2.5	-0.47	-0.59	-0.82	1.3	22

Table 3-16 Significant Main Effects of Speed on Various Measures During Alerted Stationary Trials (Study 2)

	At Braking Onset				Throughout Braking			End of Braking
Target Speed Cond.	**Mean Speed**	**Mean Range (feet**	**Mean TTC (sec)**	**Mean Req. Dec. (g)**	**Mean Actual Dec.**	**Mean Peak Dec. (g)**	**Mean Min. TTC (sec)**	**Mean Range (feet)**
30 mph	30.4	104	2.3	-0.36	-0.52	-0.71	1.3	19
60 mph	59.3	282	3.2	-0.47	-0.59	-0.81	1.8	42

The brake RT results shown in Table 3-14 are also shown in the left-hand portion of Figure 3-31. Follow-up planned comparison tests indicated faster RTs in the HUD + Non-Speech and HHDD + Non-Speech conditions relative to both the HHDD + Speech and HHDD + Brake Pulse conditions. In addition, these follow-up tests indicated faster RTs in the HHDD + Speech relative to HHDD + Brake Pulse conditions. Hence, the rank ordering of these brake RT results were as follows:

(HUD + Non-Speech=HHDD + Non-Speech) < HHDD + Speech < HHDD + Brake Pulse

The results from the remainder of the measures shown in Table 3-14 indicate a trade-off between brake RT and the effect of the HHDD + Brake Pulse cue slowing the vehicle during the "total delay time" interval discussed earlier (which includes driver RT). The consequence of this slowing can be mainly seen in the pattern of results for the mean current deceleration measure at SV braking onset, which indicates an additional -0.04 g of deceleration for the HHDD + Brake Pulse condition at SV braking onset relative to the remaining crash alert types examined. If braking was the appropriate response to an alert, this data would suggest that trade-off may actually favor the HHDD + Brake Pulse condition (relative to the other three crash alert type conditions), since at braking onset, the driver is in a more conservative kinematic scenario (lower required deceleration and higher TTC values).

The main effects of crash alert timing shown in Table 3-15 are very systematic and straightforward to interpret. These results indicate that as the crash alert timing became more aggressive, the driver was closer to the parked surrogate target at braking onset, the driver exhibited more aggressive braking (and minimum TTC) behavior, and the driver ended up closer to the parked vehicle. In addition, these results indicate that drivers' brake RTs decreased slightly (perhaps due to an increase in perceived threat) as the crash alert timing became more aggressive. It should be noted that the 0.05 g steps employed to form the three crash alert timing conditions tested are validated in Table 3-15 for the required deceleration measure.

The main effects of speed shown in Table 3-16 are also systematic and straightforward to interpret. These results indicate that in the 60 mph relative to 30 mph condition, the driver exhibited more aggressive braking behavior (although in the context of more conservative minimum TTC values), and the driver was farther away from the parked vehicle at both braking onset and at the end of braking.

The remainder of the discussion in this section will focus on interpreting the various higher-order interactions which were observed for various measures obtained at SV braking onset, throughout braking, and at the end of braking. Overall, these higher-order interactions were generally small in magnitude, of little practical significance, and not robust across related performance measures. However, a brief explanation of each of these interactions is provided below for the sake of completeness for the interested reader. (The non-interested reader is encouraged to proceed to the next section.) Also, in the event that a higher-order interaction (e.g., 4-way) encompasses a lower higher-order interaction (e.g., 2-way), a description of the higher-order interaction is provided (which is the context in which the "lower" higher-order interaction should be interpreted).

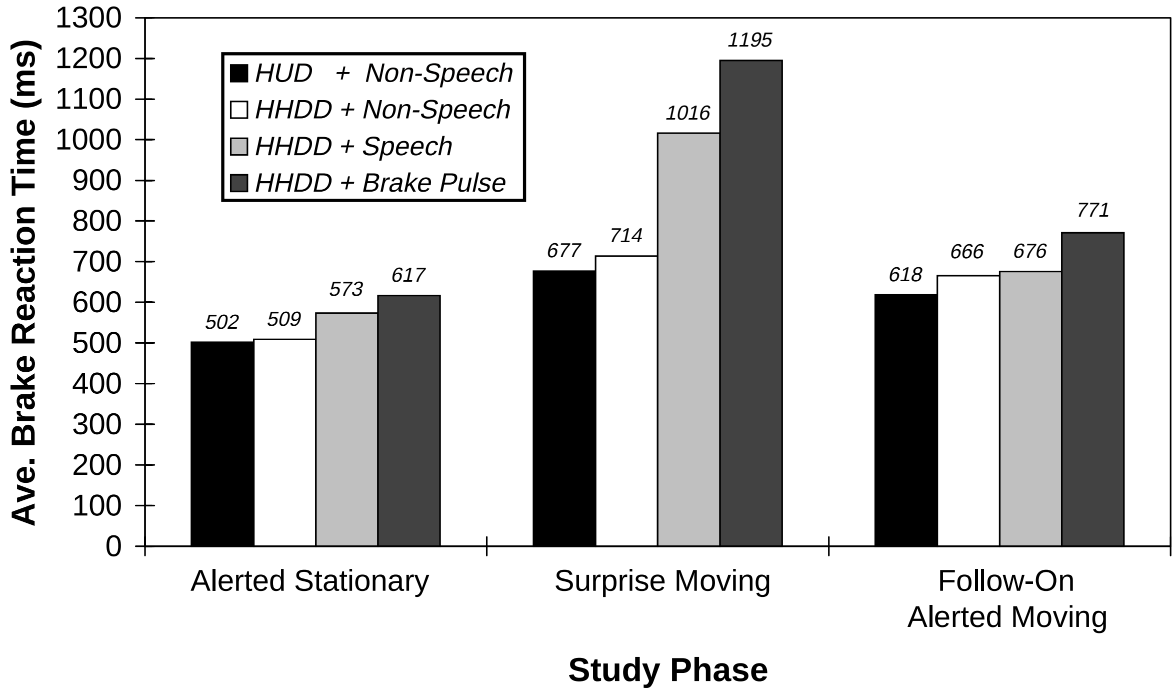


Figure 3-31 Average Brake Reaction Time as a Function of Study Phase and Crash Alert Type (Study 2)

For the brake RT measure, results indicated a Crash Alert Type x Speed interaction, and a (4-way) Age x Gender x Crash Alert Type x Speed interaction. With respect to the former interaction, in the 30 mph condition, brake RTs in the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 509, 514, 531, and 616 ms, respectively. The corresponding means for the 60 mph condition were 502, 508, 595, and 640 ms, respectively. Hence, the brake RT advantage mentioned above for the HUD + Non-Speech and HHDD + Non-Speech conditions relative to the HHDD + Speech and HHDD + Brake Pulse increased with the higher speed approach. Results from the 4-way interaction mentioned above indicated that the intermediate (i.e., second place) mean brake RT position for the HHDD + Non-Speech condition described above was far more stable in the 60 mph condition. In the 30 mph condition, the HHDD + Non-Speech brake RTs were generally quite similar to those found in the HUD + Non-Speech and HHDD + Non-Speech conditions.

For the SV deceleration at braking onset measure, results indicated an Age x Crash Alert Type, Age x Gender x Crash Alert Type, and a Crash Alert Type x Crash Alert Timing x Speed interaction. Results for the Age x Gender x Crash Alert Type interaction for the SV deceleration at braking onset measure indicated that this measure was very stable across all cell combinations of these three variables (ranging between -0.03 and -0.04 g's), except in the HHDD + Brake Pulse crash alert type condition. For this latter crash alert type, across all Age x Gender cell combinations, the SV deceleration at braking onset ranged between -0.04 and -0.12 g's. For male drivers in the HHDD + Brake Pulse crash alert type condition, the mean SV deceleration at braking onset decreased as age increased (which is consistent with the main age effect observed for brake RTs, since younger drivers may have been more likely to interrupt the completion of the brake pulse "cycle" relative to older drivers) . In contrast, for female drivers in this crash alert condition, the mean SV deceleration at braking onset was highest for middle-aged females. Results for the Crash Alert Type x Crash Alert Timing x Speed interaction for the SV deceleration at braking onset measure indicated that this measure was very stable across all cell combinations of these three variables (ranging between -0.03 and -0.04 g's), except once again for the HHDD + Brake Pulse crash alert type condition. For this latter crash alert type, across all Crash Alert Timing x Speed cell combinations, the SV deceleration at braking onset ranged between -0.05 and -0.09 g's. In the 30 mph condition for the HHDD + Brake Pulse crash alert type condition, the mean SV deceleration at braking onset *decreased* as the crash alert timing became more aggressive. In contrast, in the 60 mph condition in this crash alert condition, the mean SV deceleration at braking onset *increased* as the crash alert timing became more aggressive.

For the SV speed at SV braking onset measure, results indicated Gender x Crash Alert Type x Speed, Age x Gender, Crash Alert Type x Crash Alert Timing, and Age x Gender x Crash Alert Type x Speed interactions. Results for the Gender x Crash Alert Type x Speed interaction for this measure, indicated, that this measure was very stable across all cell combinations. Of these three variables (within 1.4 mph) for 3 out of the 4 crash alert type conditions at both speeds across all Gender x Speed condition cell combinations. However, in the 30 mph condition with the HUD + Non-Speech crash alert type, the mean SV speed at braking onset was slightly higher (2.7 mph) for female relative to male drivers. In addition, in the 60 mph condition with the HHDD + Speech crash alert type, the mean SV speed at braking onset was slightly higher (2.4 mph) for female relative to male drivers. Results for the Age x Gender x Crash Alert Type x Speed interaction for the SV speed at braking onset measure appeared to be due to a relatively unstable pattern of mean speeds across crash alert timing conditions for the middle-aged male and younger female groups.

For the range at SV braking onset measure, results indicated Crash Alert Timing x Speed and Age x Crash Alert Type x Crash Alert Timing x Speed interactions. With respect to the former interaction, in the 30 mph condition, the range at braking onset for RDP, RDP + 0.05 g, and RDP + 0.10 g conditions were 117, 104, and 91 feet, respectively. Corresponding means for the 60 mph condition were 309, 282, and 256 feet, respectively. Hence, the difference in ranges between the 30 mph and 60 mph conditions decreased as the crash alert timing became more aggressive. The 4-way interaction involving this measure indicated a general decrease in range as the crash alert timing became more aggressive for the various Age x Crash Alert Type x Speed cell combinations, with the exception of the middle-aged x HHDD + Brake Pulse x 60 mph cell combination. For this latter combination of conditions, the mean range at SV braking onset was higher in the RDP + 0.05 g crash alert timing condition relative to either the RDP or RDP + 0.10 g timing conditions.

With respect to the required deceleration and TTC measures (both measured at braking onset), there was an Age x Gender interaction for the former measure, and a (4-way) Age x Gender x

Crash Alert Type x Speed interaction for both measures. For this latter interaction, for both the required deceleration and TTC measures, the crash alert type differences shown in Table 3-14 for these measures were relative stable for the various Age x Gender cell combinations in the 30 mph condition (with the exception of the younger female group). In the 60 mph condition, this pattern of crash alert type differences was less stable, occurring for 2 to 3 of the 6 Age x Gender cell combinations.

For the actual deceleration measure (which is an alternative way of expressing braking distance), it is worth noting there were no higher-order interactions. Based on the main effects of only crash alert timing and speed reported above for this measure, this indicates that neither age, gender, nor the crash alert types played any role in affecting observed braking distances. This indirectly suggests that once drivers (regardless of age or gender) received an alert (regardless of the crash alert), braking occurred in a relatively systematic fashion based on the prevailing kinematic conditions (the latter of which was determined by crash alert timing condition).

For the peak deceleration measure, results indicated a Crash Alert Timing x Speed interaction. In the 30 mph condition, the mean peak deceleration values for the RDP, RDP + 0.05 g, and RDP + 0.10 g conditions were -0.64, -0.72, and -0.78 g's, respectively. In the 60-mph condition, the corresponding mean values were -0.77, -0.81, and -0.86, respectively. Hence, the difference between peak deceleration values across speed conditions was highest in the RDP crash alert timing condition.

For the minimum TTC measure, there was a (5-way) Age x Gender x Crash Alert Type x Crash Alert Timing x Speed interaction. This interaction indicated a general decrease in mean minimum TTC as the crash alert timing became more aggressive for the various 48 Age x Gender x Crash Alert Type x Speed cell combinations. This pattern is much more stable in the 30 mph condition (particularly for males) relatively to the 60 mph condition.

For the minimum range measure, there was also a (5-way) Age x Gender x Crash Alert Type x Crash Alert Timing x Speed interaction. This interaction indicated a general decrease in range as the crash alert timing became more aggressive for the 48 various Age x Gender x Crash Alert Type x Speed cell combinations, with the exception of the Middle-Age x Male x HHDD + Brake Pulse x 60 mph speed cell combination and the 4 Younger x Female x 60 mph speed condition cell combinations (1 combination for each crash alert type).

Surprise Moving Trial

The between-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, or HHDD + Brake Pulse) and age (younger, middle-aged, or older).). It should be noted that there were no Surprise Moving Trials in which the passenger-side experimenter intervened to assist the driver in coming to a stop.

Results indicated a main effect of crash alert type on brake RTs, which is shown in the middle portion of Figure 3-31. The trend of these RTs are identical to those found across crash alert types during Alerted Stationary Trials, and provide converging evidence for the effect of crash alert type on RTs across alerted and surprise braking event conditions. Follow-up tests indicated significantly faster brake RTs in the HUD + Non-Speech relative to HHDD + Brake Pulse conditions, and significantly faster brake RTs in the HHDD + Non-Speech relative to HHDD + Brake Pulse conditions. It is important to note that the differences in brake RTs observed across crash alert types during Alerted Stationary Trials are now exaggerated and substantially larger in the Surprise Moving Trial data (e.g., the fastest crash alert condition is nearly twice as fast as the slowest condition). Figure 3-32 provides the brake RT distribution for all drivers during these Surprise Moving Trials. It is worth noting that only one subject yielded a brake RT higher than the 1.5 second brake RT assumed for crash alert timing purposes.

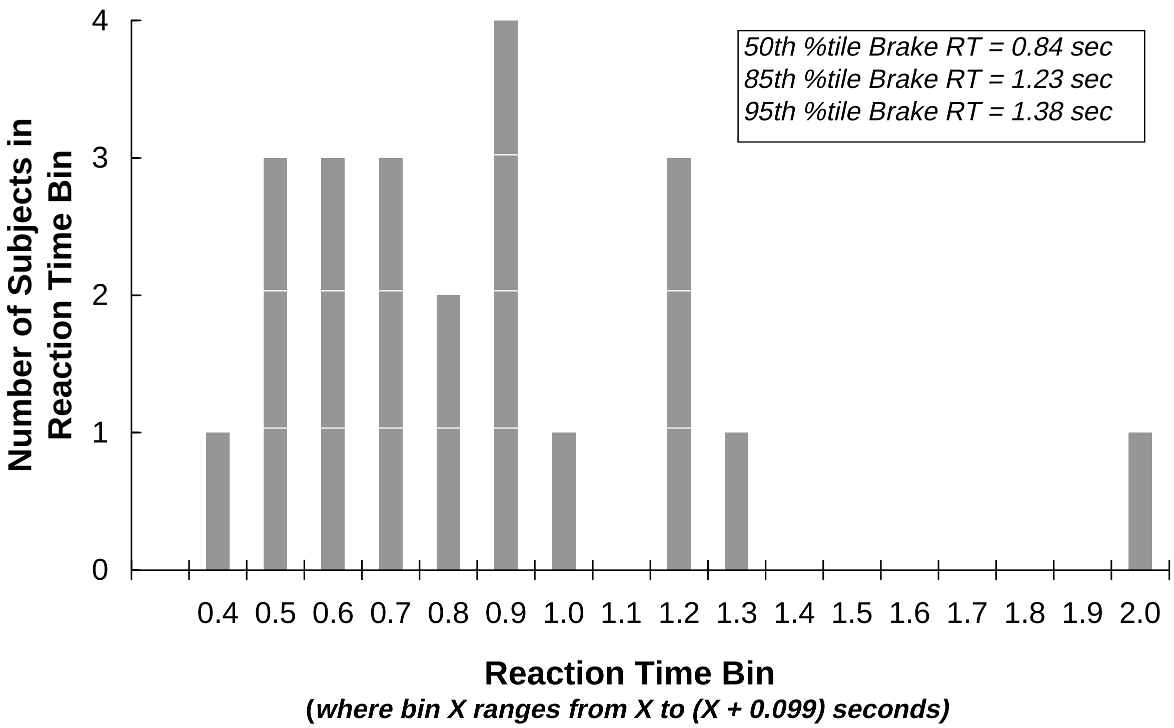


Figure 3-32 Brake Reaction Time Distribution During Surprise Moving Trials (Study 2)

Results also indicated a significant effect of crash alert type on POV speed at SV braking onset. The mean POV speed at SV braking onset for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 24.5, 25.6, 20.9, and 19.4 mph, respectively. These differences are likely to be due in large part to the RT differences cited above, since increases in RTs result in a longer time during which the POV is decelerating (and hence, reducing speed) at a constant rate.

Results also indicated a significant effect of crash alert type on POV deceleration at braking onset, and a significant Age x Crash Alert Type interaction on this measure. For younger drivers, the mean POV deceleration at SV braking onset for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 0.39, 0.38, 0.41, and 0.39 g's, respectively. For the middle-age drivers, the corresponding mean values were 0.37, 0.39, 0.40, and 0.48 g's, respectively. For the older drivers, the corresponding mean values were 0.39, 0.34, 0.56, and 0.39 g's, respectively. The mean decelerations which fall out of the 0.37-0.41 range are likely due to contributions of trials in which the POV driver braked the lead vehicle due to a brake controller failure in the POV.

In summary, results from the Surprise Moving Trials indicate that the fastest brake reactions times occurred in the HUD + Non-Speech and HHDD + Non-Speech conditions (as was found during the Alerted Stationary Trials), and that the RT advantage of these conditions over the HHDD + Speech and HHDD + Brake Pulse crash alert types was increased substantially in the Surprise Moving Trials (relative to the Alerted Stationary Trials). For reference purposes, Table 3-17 provides a list of various percentile values for key variables, nearly all of which were not involved in any of the significance effects discussed above.

Follow-On Moving Trials

The between-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, or HHDD + Brake Pulse) and age (younger, middle-aged, or older). Results indicated no statistically significant effects on the brake RT measure. For comparison purposes, results found for the brake RT measure across the various crash alert types are shown in the rightmost portion of Figure 3-31. These results indicate essentially the same (albeit statistically non-significant) trend in the means as observed during both the Alerted Stationary Trials and Surprise Moving Trial study phases, which provides strong evidence that the observed trend is very robust. One possible reason for the lack of statistically significant effects during these Follow-On Moving Trials is difficulties reported by the experimenter in getting the subjects focused on performing during these trials which were experienced immediately after the Surprise Moving Trial.

However, results did indicate a significant effect of crash alert type on SV deceleration at braking onset, POV speed at braking onset, and TTC-Case 1 at SV braking onset. These effects are shown in Table 3-18. As in the Surprise Moving Trial phase, these differences may be due in part to the (statistically non-significant) brake RT differences observed across crash alert types discussed above. Results also indicated a significant effect of age on POV speed at SV braking onset. The mean POV speed at SV braking onset for the young, middle-aged, and older groups were 26.0, 25.7, and 22.2 mph, respectively.

Table 3-17 Percentile Values for Key Driver Performance Measures During Surprise Moving Trials for Study 2 (Across All Combinations of Age, Gender, and Crash Alert Type)

Time During Which Variable was Measured	Dependent Measure (unit)	15th %tile Value	50th %tile Value	85th %tile Value
At POV Braking Onset	Time Headway (sec)	1.0	1.5	1.9
At SV Braking Onset	Brake Reaction Time (sec)	0.59	0.84	1.23
	Required Deceleration (g)	-0.28	-0.33	-0.42
Throughout Braking	Braking Distance (feet)	75	94	105
	Actual Deceleration (g)	-0.35	-0.42	-0.47
	Peak Deceleration (g)	-0.53	-0.60	-0.77
	Minimum Headway (sec)	0.6	1.2	1.6
	Minimum Range (feet)	5	17	28

Table 3-18 Significant Main Effects of Crash Alert Type on Various Measures During Follow-On Moving Trials (Study 2)

	At SV Braking Onset		
Crash Alert Type Condition	**Mean Current Dec. (g)**	**Mean POV Speed (mph)**	**Mean TTC / Case 1 (sec)**
HUD + Non-Speech	-0.02	25.9	8.6
HHDD + Non-Speech	-0.03	25.6	7.0
HHDD + Speech	-0.03	23.7	7.0
HHDD + Brake Pulse	-0.05	23.3	5.3

Subjective Measures / Questionnaire Data

Crash Alert Timing Ratings

Alerted Stationary Trials

The within-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse), crash alert timing (RDP, RDP + 0.05 g, and RDP + 0.10 g), and (approach) speed (30 and 60 mph), and the between-subjects variables analyzed were age (younger, middle-aged, or older) and gender (male or female). Results indicated main effects of crash alert timing and speed, as well as a Crash Alert Timing x Speed interaction. In the 30 mph condition, mean crash alert timing ratings for the RDP, RDP + 0.05 g, and RDP + 0.10 g crash alert timings were 4.1, 4.4, and 4.8, respectively. Corresponding mean ratings in the 60 mph condition were 3.6, 4.3, and 4.7, respectively. Hence, the ratings increased (i.e., became “later”) as the crash alert timing became more aggressive, and the difference in timing ratings between the two speed conditions examined appear to be limited to the RDP crash alert timing condition. Overall, the mean crash alert timing ratings for the RDP, RDP + 0.05 g, and RDP + 0.10 g conditions were 3.9, 4.4, and 4.7, respectively. These results indicate that under these well-controlled Alerted Stationary Trials, drivers clearly perceived the differences between the three crash alert timing approaches evaluated.

Results also indicated a main effect of age, as well as a marginally significant ($p<0.02$) main effect of Crash Alert Type. Overall, the mean crash alert timing ratings for younger, middle-aged, and older groups were 4.6, 4.4, and 4.0, respectively. Follow-up tests indicated a difference between the ratings for the younger versus older groups, while the difference between the middle-aged and older groups approached significance ($p<0.05$). Overall, the mean timing ratings for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 4.4, 4.3, 4.5, and 4.1, respectively. Follow-up tests indicated a difference only between the ratings in the HHDD + Speech and HHDD + Brake Pulse conditions.

A more insightful look at these crash alert timing data is provided in Figure 3-33. The histogram provided shows the percent of responses at each point along the crash rating scale as a function of crash alert timing. (For each crash alert timing, across all drivers, 192 total ratings were made). This figure averages over the independent variables crash alert type, speed, age, and gender, since overall, the effects reported above are modest in size (across all Crash Alert Type x Speed x Age x Gender combinations, the mean ratings ranged from 3.6-5.1 on a 7-point scale).

As can be seen in Figure 3-33, the largest percent (about half) of responses for the RDP and RDP + 0.05 crash alert timings occurred at the “just right” (i.e., “4”) point along the rating scale, whereas the largest percent of responses for the RDP + 0.10 g crash alert timing occurred at the “slightly late” (i.e., “5”) point along the rating scale. It should be noted that the percent of “much too early”, “moderately early”, “moderately late”, and “much too late” responses are extremely low (<5%) across nearly all crash alert timing conditions. The one notable exception to this trend is that over 10% of drivers rated the RDP + 0.10 g crash alert timing as “moderately late.”

Overall, these data clearly suggest that the range of timing approaches employed in this study appear to bracket driver preferences for crash alert timing. If the goal was to get a distribution of responses that were symmetrically distributed around the “just right” midpoint of the scale, it appears timing somewhere between the RDP and RDP + 0.05 g timing should be employed. Furthermore, the trade-offs between a crash alert timing approach which is slightly skewed toward early versus skewed toward late in terms of subjective ratings (i.e., RDP versus RDP + 0.05 g) is not entirely straightforward.

<u>Surprise Moving Trial</u>

The between-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, or HHDD + Brake Pulse) and age (younger, middle-aged, or older). Recall, in this study phase, that the RDP crash alert timing was used. Results indicated no statistically significant effects, with an overall rating of 4.2 (closest to “just right”). A histogram provided in Figure 3-34, shows the percent of timing responses at each point along the crash rating scale. Across all drivers, 24 total rating were made. This data indicates that 83% of the timing responses were “just right”, and 8% of the timing responses were either “slightly early” or “slightly late.”

<u>Follow-On Moving Trials</u>

The between-subjects variables analyzed were crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, or HHDD + Brake Pulse) and age (younger, middle-aged, or older). Once again, in this study phase, the RDP crash alert timing was used. Results indicated no statistically significant effects, with an overall rating of 4.0 (closest to “just right”).

Summary of Crash Alert Timing Ratings Findings

In summary, the crash alert timing ratings from the Alerted Stationary, Surprise Moving, and Follow-On Moving Trials provide strong evidence that the crash alert timing approach directly derived/modeled from the CAMP Study 1 findings (i.e., the RDP crash alert timing) does an excellent job from a driver preference perspective under a wide range of driver expectancy conditions. As is best shown in Figure 3-33, assuming “slightly early”, “just right”, and “slightly late” ratings would be acceptable to drivers using the RDP algorithm, the combined ratings of “moderately early” and “much too early” amounted to only 6% of all ratings using this crash alert timing, and “moderately late” ratings amounted to only 3% of all ratings using this timing (there were no “much too late” ratings with this timing). Consequently, in the remaining CAMP studies, the RDP crash alert timing approach (the most conservative tested in this study) was employed.

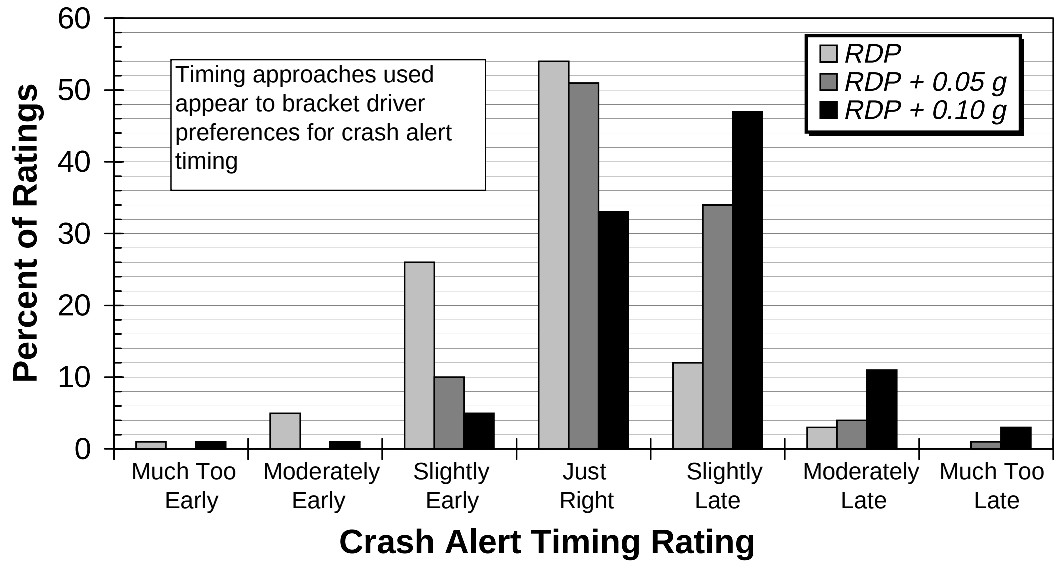


Figure 3-33 Histogram of Subjective Crash Alert Timing Ratings as a Function of Crash Alert Timing Approach During Alerted Stationary Trials (Study 2)

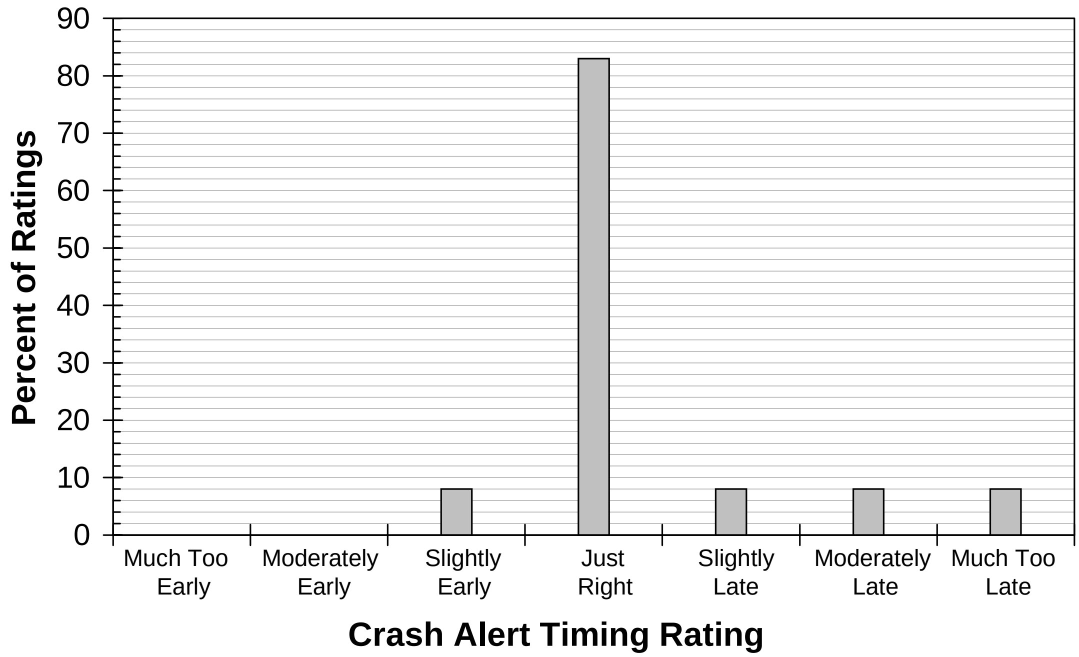


Figure 3-34 Histogram of Subjective Crash Alert Timing Ratings During Surprise Moving Trials (Study 2)

Alert Modality Appropriateness Questionnaire

Results from this questionnaire (administered at the end of each interface block of Alerted Stationary Trials) are shown in Table 3-19. Across crash alert types, the visual alerts were rated on average from “fair” to “good”, with the HUD receiving consistently higher attribute ratings than the HHDD visual alert (particularly for the intensity and size attributes). Across crash alert types, the auditory alerts were rated on average “just right”, with the speech alert receiving slightly higher mean loudness and mean duration ratings than the HHDD alert. Note that the actual dBa sound level of the non-speech and speech alerts were the same. In addition, across the three crash alert types employing an auditory alert (HUD + Non-Speech, HHDD + Non-Speech, and HHDD + Speech), 81% of drivers (ranging between 77%-83% across these alert types) indicated the radio should be muted during the alert. For the brake pulse alert, the strength of jerk and duration attributes were rated on average closest to “just right”.

Overall, these findings suggest that the crash alert modalities tested were overall rated good/just right, with the exception of the HHDD which received “fair” ratings on size and intensity. Each of the crash alert types tested were chosen to represent realistic production constraints (e.g., the direct view HHDD could not be placed higher and more central in the driver’s field of view without the telltale module interfering with a 5th %tile female driver’s view of the road.) In light of current production constraints, and the overall good/just right ratings that were attained, the identical alert modality components were used in Study 3 and Study 4, with one exception. The loudness of the auditory alerts was increased from 67.4 dBa to 73.7 dBa in the following studies.

Table 3-19 Mean Ratings from Alert Modality Appropriateness Questionnaire Findings (Study 2)

	Crash Alert Type			
Modality/Attribute	**HUD + Non-Speech**	**HHDD + Non-Speech**	**HHDD + Speech**	**HHDD + Brake Pulse**
Visual				
Intensity	4.0	3.0	3.0	2.7
Size	3.9	3.0	3.2	3.0
Color	4.0	3.6	3.5	3.4
Location	3.8	3.6	3.5	3.3
Auditory				
Loudness	3.8	3.8	4.0	N/A.
Duration	3.9	3.9	4.1	N/A.
Brake Pulse				
Strength of Jerk	N/A.	N/A.	N/A.	3.8
Duration	N/A.	N/A.	N/A.	3.6

Note: See Appendix A4 for excerpts from a copy of this questionnaire. On the attribute rating scale, for visual alerts, 2=Poor, 3=Fair, 4=Good, and 5=Excellent. For the loudness attribute, 3=Slightly Soft, 4=Just Right, and 5=Slightly Loud. For the auditory duration attribute, 3=Slightly Short, 4=Just Right, and 5=Slightly Long. For the strength of jerk attribute, 3=Slightly Weak and 4=Just Right. For the brake pulse duration attribute, 3=Slightly Short and 4=Just Right. N/A=Not applicable.

Crash Alert Appropriateness Questionnaire

An Analysis of Variance (ANOVA) was performed on each of the 14 statements employed in this questionnaire. The within-subjects variable analyzed was crash alert type (HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse), and the between-subjects variables analyzed were age (younger, middle-aged, or older) and gender (male or female). Due to the relatively large number of statistical tests carried out (which increases the probability of spuriously significant results (Hays, 1981), the criterion set for statistical significance was $p<0.01$. All statistically significant results met at least (and often exceeded) the adopted $p<0.01$ criterion.

Across all 64 cells formed by combining the 4 crash alert types by 14 sound statements, the mean statement ratings (averaging over both age and gender) ranged from 3.7 to 6.1 (where 3=perhaps disagree, 4=neutral, 5=perhaps agree, 6=moderately agree, and 7=strongly agree). Overall, there were little or no statistically significant differences found between the four crash alert types examined. The differences found, which were relatively small in magnitude, were for the following subset of the 14 statements rated:

Crash Alert Appropriateness Statements

5. This method would NOT startle me, that is, cause me to blink, jump, or make a rapid reflex-like movement.

6. This method would NOT interfere with my ability to make a quick and accurate decision about the safest driving action to take (brake, steer, brake and steer, do nothing).

8. This method would NOT annoy me if the alert came on once a week in a situation where no driving action was required.

10. This method would NOT appear out of place in a car or truck.

11. This method would clearly tell me that I am in danger and need to react immediately.

13. This method of presenting crash alert information would get my attention without being overly annoying.

For Question #8 (not annoying), there was a main effect of Crash Alert Type. The mean ratings for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 5.0, 4.7, 4.0, and 4.0, respectively. Follow-up planned comparison tests indicated significantly lower annoyance ratings in the HUD + Non-Speech condition relative to the HHDD + Speech and HHDD + Brake Pulse conditions. It should be noted that a similar trend was observed for question #9 (not annoying) at the $p<0.05$ level, which assumed alerts requiring no action occurred once a day (as opposed to the “once a week” assumption in Question #8).

There was also a main effect of Crash Alert Type for Question #6 (not interfering). The mean ratings for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD +

Brake Pulse conditions were 5.8, 5.5, 5.2, and 4.9, respectively. Follow-up planned comparison tests did not reveal any significant differences, although it is interesting that the general trend across the crash alert types examined for this question parallels that found for Question #8 (not annoying).

There was also an Age x Crash Alert Type interaction for Question #6 (not interfering), as well as for Question #5 (not startling). For Question #6, the mean ratings for younger drivers for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 5.4, 5.3, 4.4, and 4.9, respectively. The corresponding mean ratings for the middle-age drivers were 5.9, 5.6, 5.3, and 3.9, respectively, and the corresponding mean ratings for the older drivers were 6.1, 5.8, 5.9, and 6.0, respectively. These results suggest these interference effects were restricted to younger and middle-aged drivers, and that overall, interference effects were particularly associated with the HHDD + Brake Pulse crash alert type for middle-age drivers. For Question #5 (not startling), the mean ratings for younger drivers for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse conditions were 4.6, 4.6, 3.6, and 4.5, respectively. The corresponding mean ratings for the middle-age drivers were 5.8, 5.3, 5.3, and 3.4, respectively, and the corresponding mean ratings for the older drivers were 5.5, 5.1, 5.3, and 6.0, respectively. These results indicate a fair amount of disagreement on startle ratings across age groups. The two lowest mean ratings (which indicates more startle) were given for the HHDD + Speech (3.6 rating) and HHDD + Brake Pulse (3.4 rating) conditions by the younger and middle-aged drivers, respectively. In contrast, the highest mean rating (which indicated less startle) was given for the HHDD + Brake Pulse (6.0 rating) condition by the older drivers.

There were also Gender x Crash Alert Type interactions for Question #10 (harmony), Question #11 (danger), and Question #13 (good method). Across these three question (#10, #11, and #13), the lowest (least desirable) mean ratings were provided by female drivers for the HHDD + Brake Pulse condition, whereas male drivers tended to rate the HHDD + Brake Pulse condition quite favorably. For Question #10 (harmony), the mean ratings for male drivers for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse crash alert types were 5.7, 6.0, 6.0, and 6.3, respectively. The corresponding mean ratings for the female drivers were 5.6, 5.9, 6.1, and 4.8, respectively. For Question #11 (danger), the mean ratings for male drivers for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse crash alert types were 5.9, 5.3, 5.5, and 6.0, respectively. The corresponding mean ratings for the female drivers were 6.3, 6.0, 6.2, and 4.8, respectively. For Question #11 (good method), the mean ratings for male drivers for the HUD + Non-Speech, HHDD + Non-Speech, HHDD + Speech, and HHDD + Brake Pulse crash alert types were 5.9, 5.3, 4.9, and 6.3, respectively. The corresponding mean ratings for the female drivers were 6.0, 5.7, 5.8, and 4.8, respectively.

Overall, these results generally indicated less desirable statement ratings associated with the HHDD + Brake Pulse condition (e.g., annoyance), and in some instances, with the HHDD + Speech condition. In some cases for the HHDD + Brake Pulse condition (i.e., the harmony, danger, and good method statements), this trend was primarily restricted to female drivers (whereas male drivers provided favorable ratings for the HHDD + Brake Pulse condition). It should be also noted that with the exception of Question #10 (harmony), the HUD + Non-Speech condition received the highest (most desirable) mean rating for each of the statements examined.

Build an Interface Questionnaire

Results from this questionnaire (administered at the end of testing, after the Follow-On Moving Trials) are shown in Table 3-20. A few drivers were eliminated from analysis either because they failed to complete the questionnaire or because they requested that a speech and non-speech alert be presented simultaneously.

Overall, for the 1-stage alert, 3, 12, and 6 drivers requested single-, dual-, and tri-modality crash alerts, respectively. The strong driver preference against a single-modality crash alert approach (18 of 21 drivers) provides support for a multi-modality crash alert approach (particularly a dual-modality crash alert approach) in terms of accommodating driver preferences. Sixteen of 21 drivers wanted a visual alert component as part of the crash alert, 18 of 21 drivers wanted an auditory alert component as part of the crash alert, and 11 of 21 drivers wanted a brake pulse component as part of the crash alert. For those selecting a visual alert, 13 of 16 drivers chose a HUD over the HHDD. For those selecting an auditory alert, 9 drivers wanted a speech warning and 9 drivers wanted a non-speech warning. The most frequent requests (selected by 4 drivers each) were the HUD + Non-Speech and HUD + Non-Speech + Brake Pulse combinations. Hence, the preference for the HUD visual alert, and the HUD and non-speech combination as part of the crash alert, were the most interesting results. However, it should be noted that together, these two most frequent requests were only selected by 8 of the 21 drivers.

For the 2-stage alert, there was wide disagreement between drivers, which may in part be due to drivers having no direct prior experience with 2-stage crash alerts and/or having difficulties understanding the 2-stage crash alert concept. Overall, for the cautionary part of the crash alert, 15 and 5 drivers requested single- and dual-modality crash alerts, respectively. 10 of 20 drivers wanted a visual alert component as part of the cautionary crash alert, 12 of 20 drivers wanted an auditory alert component as part of the cautionary crash alert, and only 3 of 20 drivers wanted a brake pulse component as part of this cautionary crash alert. For those selecting a visual alert, 8 of the 10 drivers chose a HUD over the HHDD. For those selecting an auditory alert, 9 drivers wanted a speech warning and 3 drivers wanted a non-speech warning. The most frequent requests were the single-modality alerts (selected by 6 drivers each) involving the HUD and speech alerts. In sharp contrast to the strong multi-modality alert preferences described above for a 1-stage crash alert, for the cautionary portion of the 2-stage alert, there was a strong preference for a single-modality alert (15 of 20 drivers).

Overall, for the imminent part of the 2-stage crash alert, 10, 5, and 5 drivers requested single-, dual-, and tri-modality crash alerts, respectively. Seven of 20 drivers wanted a visual alert component as part of the imminent crash alert, 17 of 20 drivers wanted an auditory alert component as part of this imminent crash alert, and 11 of 20 drivers wanted a brake pulse component as part of this imminent crash alert. For those selecting a visual alert, 5 of the 7 drivers chose a HUD over the HHDD. For those selecting an auditory alert, 8 drivers wanted a speech warning and 9 drivers wanted a non-speech warning. As with the cautionary portion of this 2-stage alert, the most frequent requests were single-modality alerts (selected by 4 drivers each) involving the HUD and speech alerts. Once again, in contrast to the strong multi-modality alert preferences described above for a 1-stage crash alert, for the imminent portion of this 2-stage alert, there was no strong preference for a multi-modality warning (10 of 20 drivers).

In terms of alert modality, preference shifts when transitioning between the cautionary and imminent stages of a 2-stage alert. A decrease in requests for visual alerts (from 10 to 7), an increase in requests for auditory alerts (from 12 to 17), and a substantial increase in brake pulse alert requests (from 3 to 11). A more detailed look at the responses indicated that the most consistent pair (observed for only 5 of the 20 drivers) involved a HUD cautionary alert followed by a non-speech imminent alert. For 2 of these 5 drivers, a brake pulse crash alert component was also included as part of the imminent alert.

In summary, results from this questionnaire indicate a strong preference for a HUD over HHDD visual alert. No clear preferences for a speech versus non-speech alerts, and a substantially weaker preference for including a brake pulse component in the cautionary portion of a 2-stage alert relative to the imminent portion of a 2-stage alert. Interestingly, there was substantially no difference in the number of auditory alert and brake pulse alert requests in the imminent portion of a 2-stage alert relative to the 1-stage alert scenario. However, the number of visual alert requests were about twice as high in the 1-stage alert scenario relative to the scenario involving the imminent portion of a 2-stage alert. These results suggested that, overall, drivers perceived the 1-stage alert to be closer to the imminent (relative to the cautionary) portion of a 2-stage crash alert.

Table 3-20 Build an Interface Questionnaire Findings for 1-Stage and 2-Stage Crash Alert Scenarios (Study 2)

	Crash Alert Type Request					Number of Requests		
	Visual Component		Auditory Component					
Crash Alert Modality Type	**HUD**	**HHDD**	**Non-Speech**	**Speech**	**Brake Pulse**	**For 1-Stage Alert**	**For 2-Stage Caution-ary**	**For 2-Stage Imminent**
Single-Modality	✓					0	6	0
			✓			2	1	4
				✓		1	6	4
					✓	0	2	2
Dual-Modality	✓		✓			4	0	1
	✓			✓		2	2	0
	✓				✓	2	0	0
		✓	✓			1	1	0
		✓		✓		0	1	0
		✓			✓	1	0	1
				✓	✓	2	0	1
			✓		✓	0	1	2
Tri-Modality	✓			✓	✓	4	0	3
	✓		✓		✓	1	0	1
		✓	✓		✓	1	0	1

Note: See Appendix A6 for a copy of this questionnaire. Only requested crash alert types are listed.

Name the System Questionnaire

This questionnaire was administered at the end of testing, after the Follow-On Moving Trials. Results from the open-ended portion of this questionnaire were not particularly informative for assessing a driver-preferred system name. No name was mentioned more than twice. 10 of the 23 drivers included the word “Alert” as part of the proposed system name, whereas 6 of the 23 drivers included the word “Warning” as part of the proposed system name. However, the interpretation of these “Alert” versus “Warning” results is somewhat unclear, since during the driver’s testing session, the various crash alerts tested were referred to “alerts”. These references may have influenced drivers’ generation of a proposed system name.

Results for the ranking portion of this questionnaire are shown in Table 3-21. These proposed system name choices are listed in the order of number of total votes received in the top three choices (which is shown in the rightmost column of Table 3-21). There are several interesting trends that can be observed. First, the only name that was picked in the top three by more than half of the drivers was “Forward Collision Warning.” Second, three of the top four names included “Collision Warning” as part of the system name (as opposed to “Crash Warning” or “Accident Warning”). Third, the two top choices included “Forward” as part of the system name (as opposed to “Front-end” or “Rear-end”).

It should be stressed that this naming data is strictly based on driver preferences, and does not provide direct data on what driver expectations (in terms of system performance) would be associated with each of these proposed names. During the middle-portion of this CAMP FCW system program, the name of the system being addressed in this program was changed from “Forward Collision Warning” to “Rear-end Collision Warning” in an attempt to communicate to the driver that the system was designed only for responding to vehicles ahead, and not, for example, for detecting pedestrians.

In the following study (Study 3) a similar questionnaire was administered. Unlike in the current study, drivers were informed that this feature was not designed to detect pedestrians, and that this feature would occasionally alert or warn the driver under conditions which pose no threat to the driver. Furthermore, the eight choices examined in the following study were compiled by selecting the top four choices listed in Table 3-21, and adding four identical system name choices which using the word “alert” rather than “warning.”

Table 3-21 Name the System Questionnaire Findings (Study 2)

Proposed System Name	Number of Votes			
	Best Choice	Second Choice	Third Choice	In Top Three
Forward Collision Warning System	4	6	3	13
Forward Crash Warning System	7	1	1	9
Front-end Collision Warning System	4	3	2	9
Rear-end Collision Warning System	3	2	4	9
Forward Accident Warning System	0	1	6	7
Front-end Accident Warning System	3	1	2	6
Rear-end Accident Warning System	0	3	2	5
Front-end Crash Warning System	1	2	1	4
Rear-end Crash Warning System	0	3	1	4

Note: See Appendix A7 for a copy of this questionnaire. 24 drivers provided ratings.